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(54) **Title:** ELECTROMAGNETIC WAVE TRANSCEIVER

(57) The invention concerns a device for receiving and transmitting electromagnetic waves, comprising a body (18), characterized in that it comprises in combination: a receiver strip (16) incorporated in the body (18), comprising a first array of n radiating elements (30_1, 30_2, 30_3, 30_4) of microstrip structure for receiving electromagnetic waves, means (19, 20, 22, 23, 24) for transmitting electromagnetic waves of longitudinal radiation defining a radiation axis for transmitting electromagnetic waves, said means including excitation means (24) for exciting longitudinal-radiation means (19, 20, 22, 23); said radiation means being substantially of constant cross section in the body (18), perpendicularly intersecting the receiver strip (16) in a circular opening about which said radiating elements (30_1, 30_2, 30_3, 30_4) are symmetrically arranged, said receiving and transmitting means being arranged so that their respective phase centers are substantially disposed in a so-called focusing zone. Particularly applicable to the field of transmission of ultrahigh-frequency waves exchanged between a station and a dwelling or between a satellite and a dwelling, in the context of a satellite telecommunication system.

ELECTROMAGNETIC WAVE TRANSCEIVER

The invention concerns a device for receiving and transmitting electromagnetic waves.

Interactive wireless telecommunication services are expanding rapidly. These services involve telephony, facsimile transmission, television (especially digital television), the "multimedia" field, and the Internet. The equipment for these wide-area services must be such that it can be supplied at a reasonable cost. This is true in particular of a user's transceiver that must communicate with a server, usually via a telecommunication satellite. Such communications ordinarily take place in the ultrahigh-frequency range. The C-band is used, for example: from 3.7 GHz to 4.2 GHz (3.4 GHz to 4.2 GHz for expanded C-band) in receive mode and from 6.4 GHz to 6.7 GHz for transmission.

For these frequency ranges a waveguide receiver and a waveguide transmitter can normally be employed, the two waveguides being separate.

This technology is cumbersome to implement if a return link must be provided from the user to the base station in order to route the data or command stream from the user to the source of the service (in the field of "pay per view" audiovisual programming, for example). It is therefore expensive. In addition, the weight and space consumption of this technology are incompatible with use by individuals.

Document US 5,041,840 (Cipolla et al.) describes a device comprising two coaxial waveguides exciting a horn whose radiating aperture is coplanar with an array of radiating patches. The array has the same phase center as the horn. Thus, the device can transmit and receive in coincident directions.

However, the assembly comprising the array and the radiating aperture occupies too great an area in the plane of the array. The problem of space consumption is not solved.

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The invention overcomes the aforesaid drawback.

To this end, an object of the invention is an electromagnetic wave transceiver comprising a body, characterized in that it includes in combination:

- a receiver strip incorporated in the body, including a first array of n radiating elements of microstrip structure for receiving electromagnetic waves in a first frequency band,

- means for transmitting electromagnetic waves of longitudinal radiation defining a radiation axis for transmitting electromagnetic waves in a second frequency band, said means including excitation means for exciting the longitudinal radiation means,

said transmission means being substantially of constant cross section in the body, perpendicularly intersecting the receiving strip in a circular opening about which said radiating elements are symmetrically arranged,

said receiving and transmitting means being arranged so that their respective phase centers are substantially disposed in a so-called focusing zone.

Such a hybrid-type device (i.e., using waveguide and microstrip technology) can be produced at moderate cost. Its space consumption and weight are low. There is excellent isolation between the transmitted and received signals. Moreover, the use of a waveguide makes it possible to employ a broad frequency band for transmission. Above all, it should be noted that the use of such longitudinal-radiation means of constant cross section makes it possible to limit the area occupied by these means on the plane of the receiver strip in comparison to a horn, thereby permitting reception and transmission in closely spaced frequency bands and also making it possible to space the radiating elements more tightly and thus to reduce the number n thereof. Typically, the device according to the invention permits a ratio between the central frequencies of the respective transmission and reception bands of three or less, this being demonstrated at the end of the present application.

According to an embodiment, said focusing zone is reduced to a point forming the phase center of said device.

Said radiating means advantageously include a longitudinal- radiation dielectric rod whose axis coincides with the axis of the transmitted radiation.

According to an embodiment, said excitation means include a waveguide.

According to an embodiment, said radiating means include a helical device comprising a set of turns.

In this case, said excitation means can be envisioned as including a coaxial line.

According to an embodiment, n is equal to 4.

According to an embodiment, said dielectric rod is configured as a cylinder with conical ends.

According to an embodiment, said excitation means are coupled to a microstrip-based transmitter strip arranged in a cross section of the excitation means in the body for transmitting electromagnetic waves.

According to an embodiment, the device according to the invention includes a pair of probes disposed on the transmitter strip and at right angles to each other and capable of transmitting orthogonally polarized waves.

According to an embodiment, the microstrip-based transmitter strip includes a frequency conversion circuit.

According to an embodiment, the microstrip-based receiver strip includes a frequency conversion circuit.

According to an embodiment, the device according to the invention includes an intermediate strip comprising at least a portion of the frequency conversion circuit associated with the receiver strip and/or with the transmitter strip.

According to an embodiment, an auxiliary strip is associated in parallel with the receiver strip and includes a second array comprising a plurality of radiating elements respectively opposite the plurality of radiating elements of the first array and having a resonant frequency close to that (F_0) of the first array, with the result that the pair of mutually opposite arrays of radiating elements is the equivalent of a single array of expanded bandwidth.

According to an embodiment, the waveguide (19, 24) is closed by a quarter-wave ($\lambda_{GT}/4$) cavity (24_2) of a length equal to one-fourth the wavelength (λ_{GT}) of the transmitted guided wave.

A further object of the invention is an electromagnetic wave transceiver system comprising wave focusing means, characterized in that it is equipped with a device such as that described hereinabove.

Said focusing means advantageously comprise a reflector, preferably parabolic, and in that [sic] the device is arranged so that said focusing zone substantially coincides with the focal point of said reflector, said device thereby functioning as the primary source for the system.

It may also be advantageous for said focusing means to comprise an electromagnetic lens and for said device to be arranged so that said focusing zone coincides substantially with the focal point of said electromagnetic lens, said device thereby functioning as the primary source for the system.

Further characteristics and advantages of the present invention will emerge from the following description of embodiments taken as nonrestrictive examples with reference to the annexed figures, wherein:

- Fig. 1 depicts the basic concept of the path from the user to a satellite or the return path used by an embodiment of a satellite transceiver system according to the invention,
- Fig. 2 is a vertical section, taken along line A-A of Fig. 3a, of an embodiment of a device according to the invention,
- Fig. 3a is a top view, taken along line B-B of Fig. 2, of an embodiment of the receiver strip according to the invention, while Fig. 3b is a bottom view, taken along line C-C of Fig. 2, of an embodiment of the auxiliary strip according to the invention, Fig. 3c being an enlarged view of area D of Fig. 2,
- Fig. 4 is a perspective view of a variant of the invention.
- Fig. 5 shows a variant of the embodiment of Fig. 2.

To simplify the description, the same reference characters will be used in the various figures to denote elements performing identical functions. It should be noted that in this application, the combination of the guide and the dielectric may on occasion be referred to more simply as the guide.

Figure 1 depicts the basic concept of the return path used by a satellite transceiver system according to the invention.

In general, the data distributed by the transceiver system according to the invention can

originate in particular from satellites, recording studios or cable systems, or can be exchanged in the context of an MMDS (Multipoint Multichannel Distribution System), LMDS (Local Multipoint Distribution System) or MVDS (Multipoint Video Distribution System), all of which are well known to those skilled in the art. In the present embodiment, illustrated in Fig. 1, the context contemplated is that of a bidirectional satellite-user-satellite link. In this application, a satellite 1 transmits data and programs 2 that are made available to users. These data and programs 2 are picked up in the vicinity of each user via the transceiver system comprising a small-diameter antenna 3 placed on the roof of a residence 4, for example. Antenna 3 comprises a reflector 5 designed to focus the received energy at its focal point, near which is disposed a primary source 6 that picks up and radiates the energy so exchanged and includes a frequency-converting device (not shown for reasons of clarity). This converter converts the signals received via satellite to intermediate frequencies and transmits them via linking means, for example a coaxial cable 8, to an inside unit 9 disposed in the interior of the residence 4 and comprising a coder-decoder 10 connected to means for using the transmitted data, for example a television receiver 11. In the case of an office, because of its small size the antenna 3 can, of course, be placed near the balcony on the desired floor of the building. In addition, in this variant a transmitting and receiving antenna can be disposed at the top of the office building and can be equipped with a first converter to higher frequencies (in the frequency bands adjacent to 450 GHz) to distribute the signals to the various floors via a wireless link. In this case, the antenna 3 serves the purpose of collecting the signals distributed in this way and a second frequency converter has the function of converting them to intermediate frequencies.

In the invention, said antenna 3 is also used as the return path 12 or uplink path 12. The user can thus respond to an interactive service, via a remote control, for example. The data are encoded and are then transmitted by means of cable 8 to the high-frequency converter, which converts said data to a higher band of transmission frequencies. The "user" uplink path 12 transmits the return data to satellite 1, whose functions therefore include collecting and centralizing the data transmitted by users in order to retransmit them for subsequent processing. It will therefore be appreciated that the foregoing embodiment is a transceiver system in which the primary source 6 is pointed in the same direction for transmission and

reception. Similarly, in a variant of this embodiment of the invention, if the data are sent out by an earth station 13 (an MMDS station, for example) via a transceiver 14, the return data are transmitted to said transceiver [14]. Thus, in these two embodiments, the transceiver system according to the invention must include a primary source 6 whose receiving antenna and transmitting antenna are such that their respective directional patterns are maximal in one and the same direction.

According to another variant of the invention, the data 2 can originate, for example, from the satellite 1 and the return data can be transmitted to the MMDS earth station 13. This return path is shown in dotted lines in Fig. 2. Under these circumstances, the system according to the invention must include a receiving antenna and a transmitting antenna aimed in two different directions, which means that at least one of the two antennas must be defocused.

Given the significant signal attenuation introduced in the Ku band by rain in equatorial regions, the C-band can be used. In this case, the uplink path 12 operates in the 6.4 Ghz to 6.7 GHz frequency band, while the downlink path 2, i.e., the path by which antenna 3 receives the data transmitted by satellite 1, operates in the 3.7 GHz to 4.2 GHz frequency band. To be able to support new services, it is also possible to use the expanded C-band, whose downlink path 2 operates in the 3.4 GHz to 4.2 GHz frequency band.

The data transmitted over the uplink path 12 can be data relating to pay-per-view television or more generally to interactive television, which gives the user access to movies, interactive games, television shopping and remote software loading, as well as services such as database consulting, reservations, etc.

Figure 2 is a vertical section, taken along line A-A of Fig. 3a, of an embodiment of a device 15 according to the invention in which a receiver strip 16, a transmitter strip 27 and an auxiliary strip 17 are provided. Figure 3a is a top view, taken along line B-B of Fig. 2, of an embodiment of the receiver strip 16 according to the invention, while Fig. 3b is a bottom view, taken along line C-C of Fig. 2, of an embodiment of the auxiliary strip 17, Fig. 3c being an enlarged view of area D of Fig. 2 that provides a detailed overview of the constituent elements in the area of receiver strip 16 and auxiliary strip 17. Figure 4 is a perspective view of a variant of the embodiment of the invention described in Figs. 2 and 3a

to 3c.

According to the embodiment illustrated in Figs. 2 and 3a-3c, the device 15 comprises a parallelepipedal support or body 18, made of a conductive material, and a rod 19. Rod 19 comprises a cone 20 emerging from the top face 21 of said body 18, whose circular base is centered on the intersection of the diagonals of said rectangular top face 21 and whose apex points in the direction of the space to which the waves are radiating or from which they are being picked up. Said cone 20 is prolonged at its base by a cylinder 22 and terminates in a cone 23 whose apex points in the opposite direction to that of cone 20. Rod 19 formed by cone 20, cylinder 22 and cone 23 is made of compressed polystyrene, for example, constituting a dielectric antenna exhibiting longitudinal radiation, i.e., having a relatively narrow directional pattern known as a "polyrod" directional pattern. The configuration of this rod 19 explains why it is termed a cylindroconical antenna. Rod 19 functions as a waveguide, and the mode that it transmits is such that the radiation maximum is able to develop in the directional axis of the rod 19. According to a variant not shown, rod 19 is hollow. The methodology of such dielectric antennas is described in detail in the book *Techniques de l'ingénieur: Traité Electronique* [Engineering Methods: Electronics], E3 283, p. 11, Edition 3-1991.

Rod 19 is surrounded downstream of the base of cone 20 in the direction of reception of the waves by a cylindrical socket 24 whose axis D coincides with the axis of the rod 19. In the example, said socket 24 has an outer diameter of 3.66 cm and an inner diameter of 3.25 cm. Socket 24 extends inside body 18 perpendicularly to the cross sections thereof and terminates in a portion that emerges from the bottom face 25 of body 18. This socket 24 of conductive material forms a waveguide whose walls are in contact with body 18. The endmost portion of socket 24 emerging from top face 21 is open, while that emerging from bottom face 25 of socket 24 is closed by a metal strip 26. Socket 24 forms a resonant cavity with its bottom 26.

Socket 24 is split transversely into two parts 24_1 and 24_2, between which is placed, in a cross section of socket 24, the transmitter strip 27 of a microstrip-based electromagnetic-wave transmission circuit. The combination of socket 24 and rod 19 will be referred to hereinafter as the guide.

Strip 27, forming a substrate, is made of a material possessing a given dielectric permittivity, teflon glass, for example. It has a top surface 27_1 oriented toward rod 19 and a bottom surface 27_2 disposed on the other face of the substrate. Bottom surface 27_2 is metallized, forming a ground plane, and is in contact with the conductive walls of socket 24. Strip 27 is fed by two coplanar probes 280_1 and 280_2 that are etched onto top surface 27_1 and penetrate into the interior of socket 24 through openings without touching the wall of socket 24. To permit the transmission of orthogonally polarized waves, the two probes 280_1 and 280_2 are disposed at right angles to each other. Said two probes 280_1 and 280_2 are connected on strip 27, via microstrip lines 290_1, 290_2 the technology of which is known per se, to a transmission circuit (not shown in the figures). Said transmission circuit, disposed in the present embodiment on strip 27, comprises a power amplifier and a frequency converter connected to inside unit 9 by coaxial cable 8.

According to a variant of the invention shown in perspective in Fig. 4, the device further comprises a heat sink 36 disposed aft of transmission strip 27 of the microstrip-based transmission circuit and designed to dissipate the heat released by a power amplifier (not shown) arranged in the transmission circuit on strip 27. In the remainder of this description, elements performing identical functions in the subject matter of the invention may be depicted in only one of Figs. 2, 3a-3c and 4.

Part 24_2 closing socket 24 is a quarter-waveguide of wavelength $\lambda_{GT}/4$ (guided wavelength), forming a resonant cavity and functioning as an open circuit in the plane of strip 27 for the transmitted waves, λ_{GT} representing the wavelength of the transmitted guided wave.

Top face 21 comprises a substrate 28 followed successively, in the wave-receiving direction, by an array of radiating elements 29_1, 29_2, 29_3, 29_4 for receiving electromagnetic waves, a space filled with foam to a height of, for example, 4 to 7 mm, and an array of radiating elements 30_1, 30_2, 30_3, 30_4 for receiving electromagnetic waves, associated with a microstrip-based excitation circuit 31, all etched onto a substrate 320. In the present embodiment, the radiating elements of substrate 28 are composed of four flat, square patches 29_1, 29_2, 29_3, 29_4 that are etched onto bottom face 28_1 of substrate 28 facing the interior of body 18 and are evenly disposed about the center of substrate 28. The radiating elements of strip 16 consist of four flat, square patches 30_1, 30_2, 30_3, 30_4 etched onto the top face of

substrate 320 of strip 16, each of said patches 30_1 to 30_4 being disposed respectively opposite the corresponding patch 29_1 to 29_4. The bottom surface 320_1 of substrate 320, facing cavity 24_2, is metallized, forming a ground plane, and is in contact with the conductive walls of socket 24, while the top surface, facing cone 20, carries patches 30_1, 30_2, 30_3, 30_4 and excitation circuit 31.

Figure 3a details the various constituent elements of receiver strip 16. Said strip has a circular opening whose center coincides with the center of strip 16, through which socket 24 passes and about which the four patches 30_1, 30_2, 30_3, 30_4 are disposed. Strip 16 is further provided with excitation circuit 31, comprising lines 32 capable of carrying vertically polarized waves and lines 33 capable of conducting horizontally polarized waves.

Four quadrants 34_1, 34_2, 34_3, 34_4 are defined, delimited by the horizontal median line 35_1 and the vertical median line 35_2 passing respectively through the centers of the vertical and horizontal sides of strip 16. Said quadrants 34_1, 34_2, 34_3, 34_4 respectively comprise patches 30_1, 30_2, 30_3, 30_4, each patch being disposed symmetrically to the patch contained in the adjacent quadrant as defined by the horizontal 35_1 and vertical 35_2 median lines.

Each patch 30_1, 30_2 respectively has a point of connection A_1, A_2 between the top side of said patch 30_1, 30_2 and a respective vertical excitation line L_1, L_2 capable of guiding vertically polarized waves. These two lines L_1, L_2 respectively trace a right angle and meet at an intersection point C_1 located on vertical median line 35_2. Likewise, each patch 30_3 and 30_4 respectively has a point of connection A_3, A_4 between the bottom side of said patch 30_3, 30_4 and a respective vertical excitation line L_3, L_4 capable of guiding vertically polarized waves. These two lines L_3, L_4 respectively trace a right angle and meet at a connection point C_2 located on vertical median line 35_2. Proceeding respectively from these points C_1 and C_2 are two vertical lines which trace a first right-angled bend, transforming said lines into two horizontal lines etched respectively in quadrants 34_2 and 34_4, and which then trace a second right-angled bend, transforming them into two vertical lines that meet at a point C_3 located at a distance ΔL from horizontal median line 35_1. Proceeding from point C_3 is a principal excitation line for vertically polarized waves that ends at connection point C_4.

In addition, patches 30_1, 30_3 respectively have a connection point B_1, B_3 between, respectively, the right lateral side of each patch 30_1, 30_3 and, respectively, a horizontal

excitation line L_5, L_6 capable of guiding horizontally polarized waves. Similarly, patches 30_2, 30_4 respectively have an intersection point B_2, B_4 between the left lateral side of each patch 30_2, 30_4 and a horizontal excitation line L_7, L_8 capable of guiding horizontally polarized waves. Lines L_5 and L_7 meet at a point C_5 located in quadrant 34_1 and at a distance ΔL from median line 35_2, while lines L_6 and L_8 meet at a point C_6 located in quadrant 34_3 and also at a distance ΔL from median line 35_2, so that said points C_5 and C_6 are symmetrical with respect to median line 35_1. Proceeding from these points C_5 and C_6 are two lines that meet at a point C_7 located on median line 35_1, from which proceeds a principal excitation line capable of guiding horizontally polarized waves and ending at a connection point C_8.

It should be noted that the various bends traced by the excitation lines capable of guiding horizontally and vertically polarized waves are not necessarily right angles.

In the present embodiment, top face 21 is square with sides each measuring 10 cm and the body has a height of approximately 8 cm. Socket 24 has an inner diameter of 3.25 cm and an outer diameter of 3.66 cm.

Patches 29_1, 29_2, 29_3, 29_4, 30_1, 30_2, 30_3, 30_4 are each substantially $\Lambda_{GR}/2$ on a side, Λ_{GR} being the wavelength of the received guided wave. A teflon-based, ceramic-filled substrate can also be used.

Figure 3b details the constituent elements of auxiliary strip 17. Said strip comprises the four patches 29_1, 29_2, 29_3, 29_4 and a circular opening centered on the center of strip 17, through which socket 24 passes.

Figure 3c is an enlarged view of area D of Fig. 2, providing a detailed overview of the constituent elements in the region of the two strips 16 and 17. In the present embodiment, the foam height Δ can be roughly 0.06 to 0.08 times the wavelength Λ_{GR} of the received wave, i.e., roughly 4 mm to 7 mm.

In Fig. 4, the device according to the present embodiment includes an intermediate strip 37 on which is disposed a reception circuit (not shown) comprising at least a low-noise amplifier and a frequency converter. Coaxial cables (for reasons of clarity, only one coaxial cable 38 has been depicted) link connection points C_4 and C_8 to the reception circuit of strip 37 so that the received signals can be processed. The output of the reception circuit is connected, via an opening 39 made in body 18, to coaxial cable 8.

According to a variant not shown, a single oscillator can be used for the conversion to high frequencies of the signals that are to be transmitted and the conversion to low frequencies of the signals that are to be received. More generally, a plurality of single elements can be used to convert the received and transmitted signals. Strip 37 can serve as a support for these various elements. In this connection, at least one coaxial cable is arranged between strip 37 and transmitter strip 27.

Figure 5 shows an advantageous variant of the embodiment of Fig. 2. In the case wherein the wave in the high-frequency band exhibits circular polarization (right-handed or left-handed), rod 19 is advantageously replaced by a coaxial line 42 whose one end is connected to the transmission circuits and whose other end is connected to a helix 40 composed of a set of turns 41, said helical antenna operating in axial mode. The circular cross section of the helix is therefore reduced to the wavelength divided by three. As illustrated in Fig. 5, the diameter of socket 24 has a discontinuity at the level of the junction between the coaxial line and the helix. The operation of such a helical device is recounted in *Techniques de l'ingénieur* [Engineering Methods] E3283 - 12-13, Version 3-1991, and in the book *Antenna Engineering Handbook*, Richard C. Johnson and Henry Jasik, Second Edition, Chapter 13: "Helical Antennas."

The device according to the invention operates in the following manner.

The electromagnetic waves incident on reflector 5 are reflected and focused at the focal point thereof, located substantially at the geometrical center of the array of strip 17. The array of strip 16 operates on a central resonant frequency F_0, while the array of strip 17 operates on a resonant frequency F_0' that is shifted slightly with respect to said frequency F_0, so that the combination of the two strips 16 and 17 behaves as a single array of expanded bandwidth.

In addition, patches 30_1, 30_2, 30_3, 30_4 are all fed in phase and with the same amplitude by two microband power dividers, the feed to the patches having to be in phase so that the electrical fields are cumulative in the direction of propagation of the guided waves. This is because the phase shift d between two waves, for example having horizontal polarization, is $d = ß \cdot \Delta L$, where $ß = 2\Pi/\lambda_g$, λ_g being the wavelength of the guided wave.

In the preferred embodiment of the invention, the excitation is effected at B_1, B_2 and at B_3, B_4 via opposite lateral sides of the patches. Thus, patch 30_1 is excited via its right lateral

side, which creates at instant t a field E oriented from right to left, while patch 30_2 is simultaneously excited via its left lateral side, which creates at the same instant t a field E oriented from left to right, which, finally, creates fields phase-shifted by Π. Introducing a length difference of $\Delta L = \lambda_g/2$ creates an additional phase shift d such that $d = ß \cdot \Delta L = (2\Pi/\lambda_g)(\lambda_g/2) = \Pi$, which cancels the phase difference between said electric fields. This configuration improves the quality of the polarization, since it eliminates cross-polarization problems. In addition, by virtue of the symmetries that exist between the laterally aligned patches, the wave reflections cancel each other out.

Of course, in the case where the excitation of the patches 30_1, 30_2, 30_3, 30_4 is effected on the same side, the length difference becomes equal to λ_g and the phase shift therefore also returns to 2Π.

Said waves, received and carried by lines 32 and 33, are delivered via cable 38 to the reception circuit of strip 37, for example, which transmits the received signals, after they have been converted to intermediate frequencies, to internal unit 9 via cable 8.

Simultaneously, the signals originating from said unit 9 pass through the frequency conversion circuit, arranged on strip 27, for example, and feed probes 280_1, 280_2 waves to be transmitted to rod 19, which transmits the peak power in the direction of the axis D of rod 19.

Owing to the shape of the dielectric transmitting antenna, which enables it to occupy the smallest possible amount of space, reception is not disrupted. This is because the cylindroconical conformation of the guide (19, 24) upstream of the first strip (16) in the wave-receiving direction makes it possible not to disrupt the directional pattern of said array of radiating elements (30_1, 30_2, 30_3, 30_4).

The invention therefore provides a single device that is able to operate simultaneously and in a completely decoupled manner on a reception path and a transmission path.

The guide (19, 24) and the array of radiating elements (30_1, 30_2, 30_3, 30_4) are arranged so that their respective phase centers substantially coincide at a single point forming the phase center of said device, enabling said device to function as a primary source pointing in a given direction for reception and transmission, said primary source being disposed at the focal point of focusing means of a transceiver system according to the invention, such as a parabolic

antenna or an electromagnetic lens.

According to a variant of the invention not shown, at least one of the phase centers can be defocused to transmit in a direction other than the receiving direction.

The devices according to the invention can also be used in constellations of satellites in circular orbits, especially in a low earth orbit (LEO) or mid-earth orbit (MEO).

As emphasized hereinabove, the device according to the invention permits a ratio between the central frequencies of the respective transmission and reception bands that is equal to three or less, with a small number of patches, such as four, to minimize the complexity of the device.

By contrast, the prior-art device cited in the introduction to this application does not permit reception and transmission in sufficiently closely spaced reception and transmission frequency bands, respectively Fb and Fh, if the radiating elements are considered to be four in number. This is because, if d1 denotes the distance separating two radiating elements that are symmetrically opposite with respect to the phase center, d2 the diameter of the horn, Lb and Lh the respective wavelengths corresponding to the frequencies Fb and Fh, to obtain equivalent illumination at both frequencies the following conditions typically must be met:

$d1 = 0.8 \cdot Lb$ (cf. "Microstrip feeds for prime focus fed reflector antennas," *IEE Proceedings*, Vol. 134, PT.H, No. 2, April 1987, p. 190),

$d2 = 1.5 \cdot Lh$ (cf. *Antenna Engineering Book*, Richard C. Johnson, Second Edition, McGraw-Hill Book Co., Chapter 15).

In addition, for reasons of physical space consumption, it is typically necessary that $D = 0.6 \cdot d$, on the basis of which:

$Fh/Fb = Lb/Lh = 1.5/0.48 = 3.125.$

The invention is not, of course, limited to the described embodiments. For example, the guide may be selected as rectangular if one type of polarization is preferred over the other. In addition, patches 29_1, 29_2, 29_3, 29_4, 30_1, 30_2, 30_3, 30_4 can be circular or rectangular. Other shapes and configurations of the radiating elements can be envisaged, such as that in which the four flat patches 29_1, 29_2, 29_3, 29_4 are etched on the top face 28_2 of strip 17, facing the space into which the waves are being radiated.

Similarly, the length difference ΔL can be zero. Although only one configuration has

been described for the structure of the microstrip lines of strip 16, obviously other configurations could be contemplated.

It should be emphasized that the receiving and transmitting circuits of the device according to the invention can also be disposed on one and the same strip having the twofold function of supporting the reception circuit and supporting the transmitting circuit. In this case, said circuits are arranged so as to preclude any electromagnetic coupling between the reception circuit and the transmitting circuit. In addition, any crossovers between the excitation lines of the reception circuit and those of the transmitting circuit would be handled by means of bridges, for example.

CLAIMS

1. An electromagnetic wave transceiver device comprising a body (18), characterized in that it includes in combination:
- a receiver strip (16) incorporated in the body (18), including a first array of n radiating elements (30_1, 30_2, 30_3, 30_4) of microstrip structure for receiving electromagnetic waves in a first frequency band,
- means (19, 20, 22, 23, 24) for transmitting electromagnetic waves of longitudinal radiation defining a radiation axis for transmitting electromagnetic waves in a second frequency band, said means including excitation means (24) for exciting the longitudinal radiation means (19, 20, 22, 23),
said transmission means being substantially of constant cross section in the body (18), perpendicularly intersecting the receiving strip (16) in a circular opening about which said radiating elements (30_1, 30_2, 30_3, 30_4) are symmetrically arranged,
said receiving and transmitting means being arranged so that their respective phase centers are substantially disposed in a so-called focusing zone.

2. The device according to claim 1, characterized in that said focusing zone is reduced to a point forming the phase center of said device.

3. The device according to either of claims 1 and 2, characterized in that said radiation means include a longitudinal-radiation dielectric rod (19) whose axis coincides with the axis of the transmitted radiation.

4. The device according to claim 3, characterized in that said excitation means include a waveguide (24).

5. The device according to either of claims 1 and 2, characterized in that said radiation means include a helical device comprising a set of turns (41).

6. The device according to claim 5, characterized in that said excitation means include a coaxial line (42).

7. The device according to any of claims 1 to 6, characterized in that n is equal to 4.

8. The device according to any of claims 3 to 4, characterized in that said dielectric rod is configured as a cylinder with conical ends.

9. The device according to any of claims 1 to 8, said excitation means are coupled to a microstrip-based transmitter strip (27) arranged in a cross section of the excitation means in the body for transmitting electromagnetic waves.

10. The device according to claims 1 to 5 in combination with claim 9 or according to claim 8 in combination with claim 9, characterized in that it comprises a pair of probes (280_1, 280_2) disposed on said transmitter strip (27) and at right angles to each other and capable of transmitting orthogonally polarized waves.

11. The device according to either of claims 9 and 10, characterized in that said microstrip-based transmitter strip (27) includes a frequency conversion circuit.

12. The device according to any of claims 1 to 11, characterized in that said microstrip-based receiver strip (16) includes a frequency conversion circuit.

13. The device according to claim 11 in combination with claim 12, characterized in that it includes an intermediate strip (37) comprising at least a portion of the frequency conversion circuit associated with said receiver strip (16) and/or said transmitter strip (27).

14. The device according to any of claims 1 to 13, characterized in that an auxiliary strip (17) is associated in parallel with said receiver strip (16) and carries a second array comprising a plurality of radiating elements (29_1, 29_2, 29_3, 29_4) respectively opposite the plurality of radiating elements (30_1, 30_2, 30_3, 30_4) of said first array and having a resonant frequency (F_0') close to that (F_0) of said first array, so that the pair of mutually opposite arrays of radiating elements ((29_1, 29_2, 29_3, 29_4), (30_1, 30_2, 30_3, 30_4)) is the equivalent of a single array of expanded bandwidth.

15. The device according to claim 4, characterized in that said waveguide (19, 24) is closed by a quarter-wave ($\lambda_{GT}/4$) cavity (24_2) for waves one-fourth the wavelength (λ_{GT}) of the transmitted guided wave.

16. An electromagnetic wave transceiver system comprising wave focusing means, characterized in that it is equipped with a device according to any of the preceding claims.

17. The system according to claim 16, characterized in that said focusing means comprise a reflector (5), preferably parabolic, and in that said device is arranged so that said focusing zone substantially coincides with the focal point of said reflector, said device (15) thereby functioning as the primary source for said system.

18. The system according to claim 16, characterized in that said focusing means comprise an electromagnetic lens and in that said device is arranged so that said focusing zone substantially coincides with the focal point of said electromagnetic lens, said device thereby functioning as the primary source for said system.